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Proceedings of the Pacific regional peer review on Pacific Cod (*Gadus macrocephalus*) Assessment for Queen Charlotte Sound (5AB), British Columbia in 2013

December 8, 2014
Nanaimo, British Columbia

Chairperson and Editor: Rowan Haigh

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December 2015

Canada

Foreword

The purpose of these Proceedings is to document the activities and key discussions of the meeting. The Proceedings may include research recommendations, uncertainties, and the rationale for decisions made during the meeting. Proceedings may also document when data, analyses or interpretations were reviewed and rejected on scientific grounds, including the reason(s) for rejection. As such, interpretations and opinions presented in this report individually may be factually incorrect or misleading, but are included to record as faithfully as possible what was considered at the meeting. No statements are to be taken as reflecting the conclusions of the meeting unless they are clearly identified as such. Moreover, further review may result in a change of conclusions where additional information was identified as relevant to the topics being considered, but not available in the timeframe of the meeting. In the rare case when there are formal dissenting views, these are also archived as Annexes to the Proceedings.

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SUMMARY

These Proceedings summarize the relevant discussions and key conclusions that resulted from a Fisheries and Oceans Canada (DFO) Canadian Science Advisory Secretariat (CSAS) Regional Peer Review meeting on December 8, 2014 at the Pacific Biological Station in Nanaimo, British Columbia (BC).

Pacific Cod (*Gadus macrocephalus*) is a commercially important species of cod that occurs along the entire coast of British Columbia, Canada. The majority of catches are taken in Hecate Strait and Queen Charlotte Sound, where abundance is highest, although large catches have also been taken off the West Coast of Vancouver Island. Pacific Cod are taken by the groundfish trawl fishery and occasionally by hook and line fisheries.

A coastwide assessment of Pacific Cod was requested by the Fisheries Management Branch of Fisheries and Oceans Canada (DFO). An updated Area 5AB assessment had not been received for the past 2 generations for this species. This meeting reviewed the area 5AB assessment of Pacific Cod including revisions as recommended at the January 9-10, 2014 Regional Peer Review. Given the apparent high productivity of Pacific Cod, updated advice has been requested to respond to changes in stock abundance in a timely manner.

Meeting participants included representatives of DFO Science, DFO Fisheries Management, the Fishery Resource Analysis and Monitoring Division (Northwest Fisheries Science Center, NOAA, USA), the Canadian Groundfish Research and Conservation Society, the Commercial Industry Caucus (trawl), the Sport Fishery Advisory Board, the Council of Haida Nation, the Canadian Parks and Wilderness Society, and the Centre for Science Advice – Pacific (CSAP).

The conclusions and advice resulting from this review will be provided in the form of a Research Document and a Science Advisory Report providing advice from Science to managers and other clients. These documents will be publicly available on the DFO's CSAS website.

Compte rendu de l'examen par les pairs de la Région du Pacifique sur l'évaluation de la morue du Pacifique (*Gadus macrocephalus*) du bassin de la Reine Charlotte (la zone 5AB), Colombie-Britannique en 2013

SOMMAIRE

Le présent compte rendu résume les discussions pertinentes et les principales conclusions de la réunion d'examen régional par des pairs du Secrétariat canadien de consultation scientifique de Pêches et Océans Canada (MPO), qui a eu lieu le 8 décembre 2014 à la Station biologique du Pacifique de Nanaimo, en Colombie-Britannique.

La morue du Pacifique (*Gadus macrocephalus*) est une espèce de morue importante pour la pêche commerciale. Elle est présente sur toute la côte de la Colombie-Britannique (Canada). La majeure partie des prises surviennent dans le détroit d'Hécate et le détroit de la Reine-Charlotte, où l'abondance est la plus grande, bien que l'on ait aussi effectué des prises importantes le long de la côte ouest de l'île de Vancouver. La morue du Pacifique est pêchée au chalut à poisson de fond et, à l'occasion, à la ligne.

La Direction de la gestion des pêches, de Pêches et Océans Canada (MPO), a demandé une évaluation de la morue du Pacifique sur l'ensemble de la côte. On n'a reçu aucune évaluation à jour de la zone 5AB pour les deux dernières générations de cette espèce. Cette réunion a permis d'examiner l'évaluation de la morue du Pacifique dans la zone 5AB, de même que les révisions comme le recommandait l'Examen régional par les pairs des 9 et 10 janvier 2014. Compte tenu de la forte productivité apparente de la morue du Pacifique, on a demandé une mise à jour de l'avis pour réagir en temps opportun aux changements de l'abondance des stocks.

Les participants à la réunion provenaient du Secteur des sciences du MPO, de la Gestion des pêches du MPO, de la Fishery Resource Analysis and Monitoring Division de la NOAA (États-Unis), de la Canadian Groundfish Research and Conservation Society, du regroupement commercial du secteur industriel (pêche au chalut), du Conseil consultatif sur la pêche sportive, du Conseil de la nation Haida, de la Société pour la nature et les parcs du Canada et du Centre des avis scientifiques – Région du Pacifique (CASP).

Les conclusions et les avis qui découlent de cet examen seront présentés sous la forme d'un document de recherche et d'un avis scientifique offrant des conseils du Secteur des sciences aux gestionnaires et à d'autres clients. Ces documents seront accessibles au public sur le site Web du SCCS du MPO.

INTRODUCTION

This proceedings document summarises the main discussion points arising from the regional peer review (RPR) meeting on December 8, 2014 held at the Pacific Biological Station in Nanaimo to review a revised assessment for area 5AB Pacific Cod (details below). The Terms of Reference appear in Appendix A. Working paper written reviews appear in Appendix B. The agenda and participants for the RPR meeting appear in Appendices C and D, respectively.

The conclusions and advice resulting from this RPR will be provided in the form of a Canadian Science Advisory Secretariat (CSAS) Science Advisory Report (SAR) to inform fishery management decisions. The SAR and supporting Research Document will be made publicly available on the CSAS website.

REGIONAL PEER REVIEW MEETING

Working Paper:	Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait (5CD) and Queen Charlotte Sound (5AB) in 2013 (revised). CSAP WP 2014-15/GF11.
Authors:	Robyn Forrest, Kate Rutherford, Lisa Lacko, Rob Kronlund, Paul Starr
Reviewers	Caihong Fu, Marine Ecosystems and Aquaculture Division, Pacific Biological Station, Nanaimo BC, DFO
	James T. Thorson, Fishery Resource Analysis and Monitoring Division, Northwest Fisheries Science Center, Seattle WA
Chairperson:	Rowan Haigh (Groundfish, MEAD, PBS, DFO)
Rapporteur:	Maria Surry (Groundfish, MEAD, PBS, DFO)
Presenter(s):	Robyn Forrest (Groundfish, MEAD, PBS, DFO)
Meeting:	Dec. 8, 2014, Seminar Room, Pacific Biological Station, Nanaimo BC

WRITTEN REVIEWS

Unless otherwise specified, text in non-italic font reflects the questions and comments from the reviewers. Italicised text reflects the responses and comments by the authors. The RPR meeting participants (Appendix D) are collectively called "participants" herein.

The primary author presented the new analyses, results, and recommendations for Pacific Cod in Queen Charlotte Sound (5AB). Analyses and results from Hecate Strait (5CD) were presented and accepted (with minor revisions) at the January 2014 meeting, and were not discussed at this meeting.

One of the reviewers asked a few questions for clarification during the presentation.

1. Where does the fixed CV come from in the reference case?

   The authors responded that the value (0.25) was arbitrary and is discussed in the Working Paper.

2. Regarding the priors, where does the growth rate originate?

   The author responded that the growth rate was the same as that used in the 2004 assessment, based on Westrheim publications (in working paper) and on historical usage. As there was a lack of information on growth rates for Pacific Cod, the authors felt that it was best not to change the growth rate.

Note: Further discussion on growth rates appears in the General Discussion section later.

The presenting author gave a brief overview of a new age validation method being used for Pacific Cod in Alaska, and, based on preliminary results from Alaska, noted that BC assessments could possibly also be overestimating age.

REVIEWER 1: CAIHONG FU (DFO)

The written review by Caihong Fu appears in Appendix B. Here, responses by authors to reviewers are presented. Caihong Fu attended the meeting in person.

The reviewer acknowledged that the authors had adequately addressed issues identified at the Jan 2014 meeting. The current review only addressed issues in Appendix D ("Mean Weight Data") of the working paper.

1. The reviewer questioned the differences between length frequencies before and after 1996. If the sampling issues were the same in both 5CD and 5AB, why were the length frequencies so different (refer to Figure D8a in the document)?

   The authors responded that the general characteristics of length frequency were quite similar between the two areas.

   The reviewer noted that there were more small fish concentrated in the later part of the time series in 5AB.

   This was likely a function of sampling effort. The authors also noted that the early part of the time series was sampled at the fish plants, and therefore only represented Pacific Cod that arrived there, and would not have represented discarded fish. Also, the sample size for 5AB length samples was much smaller than for 5CD, which could result in biased results.

   The reviewer maintained that larger sample sizes in 5CD should have resulted in more small fish in 5CD than in 5AB.

   A participant noted that the length frequency represents fish that onboard observers sampled, but there is no way to know if this sampling was representative of the catch. There is also no way to know how samples were selected prior to the onboard observers. The participant also noted that the size range was quite similar between the areas (5AB and 5CD).

2. The reviewer observed that aside from knowing whether samples were representative of the two populations, differences in length frequencies between the areas could imply two possibilities: (1) distributional differences existed between younger and older Pacific Cod, where younger Pacific Cod tended to stay in 5AB; and/or (2) spatial distributions changed over time (or after 1996), where younger Pacific Cod may have moved south.

   The authors agreed and emphasized the need to incorporate spatial analysis in future assessments.

3. The reviewer thought that the working paper should indicate that length-bias issues apply to both areas, not just to 5AB.

   The editor notes that additional discussions regarding uncertainties in length data are summarized under General Discussion.

REVIEWER 2: JAMES THORSON (NOAA)

The written review by James Thorson appears in Appendix B. Here, responses by authors to reviewers are presented. James Thorson attended the meeting via teleconference.

The reviewer strongly endorsed using the current assessment as the basis for providing science advice, stating that delays which could lead to detrimental effects on long-term management performance should outweigh the desire to perfect the model.

1. The reviewer asked why the problem with pre- and post-1996 length data represented irreducible uncertainty in the model. Why not use the modern ratio of discard:keeper to estimate the historic discarded lengths?

   The authors thought it might be possible to rebuild historic length data using historic mesh size to derive selectivity, and suggested that this was a topic for future work.

   An industry representative stated that one of the differences between 5AB and 5CD is that before 1996 fishers discarded only the smallest fish, while after 1996 there were years when they discarded all the catch, applying the total mortality against their quota holdings (therefore, modern ratios may not apply to historic data).

   The authors stated that this would show up in the observer data for trips with onboard observers (1996 on). Also, the choice of which fish are retained or discarded is made by the vessel operator, not by the onboard sampler; therefore, retention curves would not remain constant. The key thing to look at is mesh size.

2. The reviewer thought that future assessments should consider an age-structured model for Pacific Cod, suggesting that delay-difference models are essentially age-structured.

   The authors mentioned that they had considered age- and length-structured models, but the problem of estimating selectivity dissuaded their use. Despite this limitation, the authors thought that the reviewer's suggestions was worth pursuing. Clarification would enable the relaxing of some assumptions.

3. The reviewer still had concerns regarding the leading parameters used for data-weighting, specifically the assumed variance (additive vs. multiplicative). This was mentioned in Thorson's previous review (of Pacific Cod 5CD), but the reviewer acknowledged that the results of sensitivity analyses provided by the authors indicated that this was not a huge issue. That is, it should not affect the viability of the model for providing harvest advice.

   The authors agreed with the reviewer's comment and suggest that the issue could be evaluated further in future assessments.

GENERAL DISCUSSION

The RPR meeting participants (Appendix D) are collectively called "participants" herein. Unless otherwise specified, text in non-italic font reflects the questions and comments from the participants. Italicised text reflects the responses and comments by the authors.

UNCERTAINTY IN LENGTH DATA

A participant asked about the rationale for using both retained (keepers) and discarded samples post-1996, when pre-1996 there was a lack of reported discards.

- Since we know that including both keepers and discards will change the mean length and weight and we see a big impact in the model results, why do we not just use the keepers after 1996?

- *If all the data are not included, there are few or no samples in 5AB. At the previous review meeting (Jan 2014), this was deemed unacceptable as some years had one or no samples.*

A participant asked whether there are different mesh requirements in 5AB and 5CD (which would impact the size of fish caught).

- Industry and Management representatives responded that the requirements have been the same for about the past two years. Previously there may have been smaller-mesh nets in 5AB (see Table 5 of the Research Document for summary of mesh regulations). One participant noted that areas 5CD and 5AB had different mesh size regulations that were not reconciled until 2011.
- Industry representatives noted that an additional effect of current larger mesh sizes is that they don't see the peaks of abundance early (when the fish are small). This means that they only see fish in abundance for about two years and then they are gone again.
- General discussion led to an acknowledgement that changing mesh size regulations could have had a large effect on the interpretation of model results, because the delay difference assessment model assumes constant selectivity. This is acknowledged in the Research Document as a possible source of bias in the assessment. However, the relative lack of survey age composition data for Pacific Cod, and the complete lack of age composition data from the commercial fishery, mean that estimation of commercial selectivity in an age-structured model is currently not possible.

VARIABLE GROWTH RATE

One of the reviewers observed that varying growth rate, rather than fixing growth rate as done in the current model, would allow the scaling up and down of the exploitation rate. The residual fit of the annual mean weights had a "lumpy" pattern, suggesting that information was missing. Estimates of individual growth rate might clear up the residual pattern.

- The reviewer asked if some scenarios had predicted mean weights that are systematically different. Incrementing L_0 and L_∞ by a fixed proportion should scale up predictions of mean weight without affecting other components of the model. The reviewer emphasized that this should not affect the viability of the current model to provide advice.
    - *The authors agreed that assuming a constant length-weight relationship could bias model results. Constant growth is one of the key assumptions of delay difference models. Addressing this concern would require an age- or length-structured modelling approach, which is not straightforward given current lack of ageing data and concerns about bias in the available length data (see above).*

SPATIAL ANALYSIS

A recurrent theme in discussions was the need for spatial analysis in the future.

- The authors suggested that Science does not devote enough resources to looking at all the data available (e.g., spatial fishery logbook data).
- The authors suggested that in future they could look at Pacific Marine Fisheries Commission (PMFC) areas "5ABCD" as single population fished by a single fleet or by two fleets with different selectivities in each area.
- The authors and a participant noted that such an implicitly spatial approach is also being evaluated in the Pacific Halibut and Pacific Hake assessments.

- Industry representatives suggested that the current synoptic survey design may not accurately reflect Pacific Cod abundance because in any given year, the placement of the random blocks might miss Pacific Cod "hot spots", or alternatively, the surveys may hit a Pacific Cod "hot spot", making the catch rate anomalously large.
- One of the reviewers noted that extreme catch events can be built into models (instead of treating them as outliers).
- A reviewer commented that the methodology of dealing with spatial issues is not well understood.
- A participant suggested that the R package PBSmapping (Schnute et al. 2015) provides a quick and easy tool to characterize spatial changes in the fishery. One scenario suggested was to consider "location" as a spatial block and observe its historic change or run a model that looks at the same fishing ground continuously. Looking graphically at differences in the fishery is relatively easy.
    - *One of the authors noted that Science does not have good historical data, so there will be limitations on what can be done with historical spatial information.*
- One the reviewers noted that he authored a paper (Thorson et al. 2015) that describes a spatial model, but it does not include movement. This limitation can propagate uncertainty about areas that are not directly observed when only CPUE data are available.

SEPARATE FISHERIES

There was general agreement amongst participants that in area 5AB, the pre- and post-1996 periods represent essentially separate fisheries.

- Management measures implemented in 1996 (onboard observers for groundfish trawl vessels and the enforcement of TAC cuts) changed the behaviour of the trawl fleet.
- An Industry representative stated that when ITQs (individual transferable quotas) were implemented in 1996/97, there was basically no change in fishers' behaviour in 5CD because the fish in 5CD had always been larger and of better quality.
- Industry thought there was no quota in 5AB prior to ITQs, so fishers were not concerned about how much was caught in this area. Once quotas were introduced in 5AB, the Pacific Cod fishery became an avoidance fishery (the quotas were small so fishers avoided known "hotspots" to avoid catching too much).
- When looking at the time series for the 5AB fishery, industry saw a strong "signal" in terms of avoidance of Pacific Cod.
- Changes in behaviour and discarding before and after 1996 led the authors to exclude CPUE from the model after 1996. Industry representatives and the Technical Working Group for the assessment have strongly advised the authors that management changes in 1996 affected the quality of data available for the stock assessment and that post-1996 CPUE data could not be considered an unbiased index of abundance.

OTHER MODELING ISSUES

The participants discussed additional modelling issues to consider in future assessments for this stock.

- Participants noted that if the current model were to be used again, the authors might consider additional sensitivity runs:

- run the model without an informed prior on q;
- run the model without fish weights and recruitment.
    - *The authors asked whether they could justifiably request a larger set of fins to be aged (archival and recent fins). They also noted that there are currently no commercial age structures, but suggested the creation of an age-length key to go back in time.*

- There was general agreement that more ages would allow a better specification of growth, estimation of the parameters K and L_∞, and an investigation of whether there is density-dependent growth.
- One participant suggested incorporating age and length data directly into the population model. If only weight is used, potential information for length is lost (e.g., does the biomass comprise lots of small fish or fewer large fish?).
- Another participant suggested using a length-based model before trying more aging.
    - The authors noted that selectivity would be a problem (as with age-structured models).
    - A participant noted that other jurisdictions have run pseudo-length based models (using age-length keys), which is not necessarily the best way to deal with lengths because the distribution of lengths is not equivalent to the distribution of ages.
    - One of the authors with some experience using length-based models responded that a true length-based model has a transition matrix, where at any given time step (day, month, season, year, etc.) there is a probability of going to the next length class, staying the same, or shrinking (age is not represented). These models are very demanding – there is even the capacity to have a length frequency within an age distribution. Length data may not be very informative per se, but if done properly these models can estimate selectivity and maturity. A true length-based model could be better than a delay-difference model.
        - *The authors noted that there is a tradeoff between obtaining a greater understanding of Pacific Cod and other avenues of research. However, there could be spin-off benefits to other species from doing comprehensive work on one species.*

- The participants pointed out that the serious investments of time and money necessary to address critical problems need to be represented in the SAR.

REFERENCE POINTS AND DECISION TABLES

As was agreed for 5CD, historical reference points were proposed for 5AB based on estimated biomass for the period 1956–2004, and the working paper included decision tables based on those reference points. There was lengthy discussion on whether this was a valid approach for 5AB, and on what alternatives might still allow for the provision of advice.

The participants debated whether they could trust the 5AB biomass estimates from the model, or even if the model is appropriate for 5AB.

- Industry representatives indicated that higher catches in the early 1990s in both 5AB and 5CD coincided with the ramping up of fishing effort in anticipation of ITQ implementation in 1997 (the fleet went from 60-80 boats to more than 120 boats in 1996). At the same time, lower trip limits on rockfish were occurring, so there was more pressure on shallower areas (possibly resulting in larger catches of Pacific Cod).

- One participant noted that during the same period, Pinniped (seal) abundance had increased three-fold.
- A participant suggested that a retrospective analysis could have shown whether the model always predicts a recovery that doesn't happen. The authors agreed that they should have done this.
- The participants noted that historic catches were underestimated (because no discards were recorded or estimated). They also noted that in the pre-1996 period, the model was largely driven by CPUE (which is driven by catch). The authors noted statements in the primary literature, and from the fishing industry, that pre-1996 CPUE is considered to be indicative of available biomass in 5CD, and that this may therefore also be true in 5AB.
- One participant noted that changes in growth or selectivity, which may not have been captured in the model, could result in the lower biomass estimates presented. Other participants were concerned about selectivity in the survey index, as the Queen Charlotte Sound Synoptic survey was one of the main sources of information in the model during the later part of the time series. It was noted that sensitivity analysis should have been conducted on the prior for catchability q (survey q) in 5AB, as q is more influential in 5AB than in 5CD (survey q may be driving the biomass).
- The CSAP representative reminded the participants that they need to decide whether there is a scientifically sound basis for considering alternative interpretations for lower biomass or agreeing that biomass is not represented.

Basing reference points on the 1956–2004 period (which includes the higher pre-1996 biomass estimates) suggested that the current low biomass estimates put the stock in DFO's "Cautious" or "Critical" zones. The participants considered whether the time frame 1956–2004 was an appropriate window for historical reference points for 5AB given the following points.

- Industry had provided information indicating that the time periods pre- and post-1996 represented two different fisheries in 5AB, with very different characteristics.
- There was large uncertainty about whether the length samples used to generate mean weights were representative of the population in 5AB (mean weights were highly influential in the model post-1996).
- No survey time series existed in 5AB until 2003; therefore, there were no fishery-independent data to bridge the pre- and post-1996 time periods (as there were in 5CD).
- It was not possible to determine whether the lower biomass estimates post-1996 were due to any of the following, or a combination that cannot be disaggregated:
  - a change in productivity;
  - below-average recruitment; or
  - management changes that resulted in an avoidance fishery in 5AB.
- There was no indication that survey abundance trends were trending downwards. Also, the Pacific Cod fishery seems to have stable for the past 20 years.
- There was no rationale for automatically adopting the same time period as 5CD for calculation of historical reference points.

Proposed alternative reference points

- There was a proposal to include all reference points as they appear in the working paper along with strong caveats and to let managers decide what to do.
    - *The authors thought that this would likely be inappropriate as managers are not necessarily equipped to make these choices.*
- There was a proposal to generate reference points based on the post-1996 period.
    - *The authors calculated various measures based on 1996–2012 estimates only:*
        - *average biomass = 890 t (compared to 4,360 t for the entire time series);*
        - *average fishing mortality = 0.36 (compared to 0.32 for the entire time series);*
        - B_{min} = *267 t.*
- Many RPR participants felt that post-hoc choosing from the model, or "cherry picking" parts to validate beliefs, may not be defensible. Others questioned the wisdom of basing reference points on a component of the model reconstruction that is one tenth as high as the rest of the time series.
- The participants also noted that when using historical-based reference points under the precautionary approach policy, the historical period chosen should be a productive one. They generally trusted the early part of the time series for reflecting changes in biomass, but not so the later part.
- After much discussion, the participants agreed that biomass-based reference points seemed inappropriate for two disconnected regimes or time periods. Opinion converged on using a constant fishing mortality rate harvest control rule (*F*-based) based on the following rationale:
    - It would essentially maintain the status quo, i.e., continue the historic harvest rate; and
    - The average fishing mortality was relatively insensitive to the time period used (see above) despite some concerns that *F* may be underestimated given the issues with post-1996 data.
- There was concern by all participants that an *F*-based harvest control rule alone cannot be adopted without establishing limit reference points.
    - *The authors noted that the precautionary approach definition of a fishing mortality that doesn't result in a stock decline is very difficult to interpret with a variable stock like Pacific Cod.*
- The CSAP representative noted that when provisional-type rules (e.g., 0.4 B_{MSY} and 0.8B_{MSY}) cannot be supplied, the authors and/or participants need to provide some guidance on what to use instead.
- One participant suggested setting the limit to 50% of the current mean biomass, but this is quite arbitrary and relies on estimated biomasses that the participants already rejected for calculating reference points.
- Another participant suggested using the survey time series of abundance indices – for example, monitor whether the survey index drops below a certain percentage of the mean of the survey time series (50% of the mean was suggested). If this limit is triggered, then some management action is required. This type of limit requires a review of the controlling factor (i.e. survey index) whenever a new value is obtained. The precautionary approach

would be satisfied in that Science monitors something recent (to coincide with the fishery) and regularly (or at least with a period shorter than that of a typical groundfish assessment cycle).

- One of the reviewers suggested a yield-per-recruit calculation. The model already has strong assumptions about individual growth schedule (L_0, L_∞, and k), natural mortality rate (M), maturity ogive (knife edge at a_{mat}) and selectivity schedule for both surveys and fisheries (both are knife edge at a_{mat}). Therefore, one can compute the yield-per-recruit as a function of instantaneous, fully-selected fishing rate F. Given a per-recruit proxy ($F_{10\%}$ or other percentage; Zhou et al. 2012), a target/limit F can be calculated, and this can be converted to a target exploitation fraction (see Zhou et al. 2012 for details).
- The same reviewer also stated that an alternative to the use of a per-recruit proxy for F_{MSY} is the historical F (averaged over their chosen time period), converted to an exploitation fraction.
- One of the participants questioned why one would believe model-generated fishing mortality rates but not biomass. The authors responded:
    - *Fishing mortality rate can be calculated over the entire time series rather than just picking ad hoc portions of the model output;*
    - *Fishing mortality appeared to be relatively insensitive to the time period used to estimate it, in contrast to the historical biomass, which was extremely sensitive to the period chosen. The difference in F was only 0.04 over the whole series whereas the difference in biomass was 5,000 t; and*
    - *One can also calculate F using a per-recruit method (see reviewer comment above).*
- One participant questioned the period for calculating F: if the period is the whole time series, would it change every year? If so, would using F-based reference points require that a new assessment be done every year?
    - The CSAP representative responded that there are national precedents for "cranking a model" in subsequent years without doing a full assessment
    - *The authors questioned the utility of spending any additional time in continuing to use this model in future years, given the flaws that had already been discussed.*
    - A participant noted that for multi-year assessments Ottawa deems it acceptable to continue the status quo unless surveys show otherwise (i.e., it's not necessary to crank the model). If Science believes that the stock is in a productive period then a "wait and see" approach is sufficient. managers noted that they already refer to the survey indices when making management decisions.
    - The CSAP representative noted that adoption of F-based reference points requires that they be called provisional, i.e., they are the best Science can do for now. However, the time frame allows action before harm can occur.
    - *The authors questioned whether reference points are required, as none have been provided previously for this stock, or whether a decision table of probabilities that the stock will increase or decrease would suffice. Is a harvest control rule alone appropriate? As soon as a decision table is introduced, any harvest control rule is usually replaced by a catch that satisfies probabilities acceptable to managers.*
- Fishery managers stated that they prefer to see decision tables, but do take reference points into consideration.

CONCLUSIONS

CONSENSUS ON PAPER ACCEPTABILITY

The working paper was accepted with revisions outlined in the following sections.

CONSENSUS ON 5AB PACIFIC COD ASSESSMENT

- Use provisional reference points based on estimates of fishing mortality rate (*F*). The working paper should clearly state that these reference points are provisional only, along with justification and caveats.
- Use the 1956-2004 period to generate reference points based on fishing mortality.
- Exclude all biomass-based reference points.
- Do no use the additional reference points (biomass or fishing mortality) calculated during the meeting based on the post-1996 biomass estimates (and do not include them in the decision tables).
- Monitor the QCS Synoptic survey biomass index for signs of population compromise. Specifically, the trigger for action would occur when any additional index point (after 2013) falls below 50% of the mean survey indices prior to the new index point. If this occurs, additional analysis will be required and an updated assessment could be requested.
- Present model-averaged results using *F*-based reference points only in the decision tables of the revised working paper (remove all results using biomass-based reference points).
- No further sensitivity analyses for this model are needed or requested for the working paper to be accepted as suitable for providing advice.
- While the authors prefer to discuss fishery external forces in a separate document, provide sufficient explanation about the Pacific Cod 5AB fishery to clarify the issues with the CPUE time series in the revised working paper.

INSTRUCTIONS TO AUTHORS

- For the Pacific Cod 5AB stock, provide provisional reference points based on estimates of fishing mortality rate (*F*) only; remove those based on spawning biomass (*B*). Clearly state in the final Research Document that these *F*-based reference points are provisional only, along with justification and caveats.
- Only present decision tables using the *F*-based reference points.
- Provide advice to managers on how to monitor the 5AB stock in a precautionary manner. Specifically, the Queen Charlotte Sound Synoptic survey abundance index should be monitored, and the trigger for management action would occur when any additional index point (after 2013) falls below 50% of the mean survey indices prior to the new index point. Management action might include request for additional analysis and an updated stock assessment.
- Include sufficient explanation of the fishery's external forces that would affect the Pacific Cod 5AB fishery and its effects on the commercial CPUE time series after 1996.

GENERAL RECOMMENDATIONS

- Study the spatial distributions and stock structure in two areas for Pacific Cod (5AB and 5CD) to achieve more credible stock assessments.
- Analyze post-1996 (observer) data to estimate both a selectivity curve and a separate retention curve (where each could be logistic at age, at size, etc.) to bridge data prior to observers and data with observers. (Retained fish are a product of selectivity and retention curves.)
- Implement model averaging when multiple models provide equally credible results.
- Increase the effort on ageing otoliths from Pacific Cod in area 5AB.

REFERENCES

Schnute, J.T., Boers, N., Haigh, R., Grandin, C., Chabot, D., Johnson, A., Wessel, P., Antonio, F., Lewin-Koh, N.J., and Bivand, R. 2015. PBSmapping: Mapping Fisheries Data and Spatial Analysis Tools. R package version 2.68.68. (Accessed 25 March 2015)

Thorson, J.T., Shelton, A.O., Ward, E.J., and Skaug, H.J. 2015. Geostatistical delta-generalized linear mixed models improve precision for estimated abundance indices for West Coast groundfishes. ICES Journal of Marine Science, Advanced Access. (Accessed 25 March 2015)

Zhou, S., Yin, S., Thorson, J.T., Smith, A.D.M., and Fuller, M. 2012. Linking fishing mortality reference points to life history traits: an empirical study. Can. J. Fish. Aquat. Sci. 69: 1292-1301. (Accessed 25 March 2015)

APPENDIX A: TERMS OF REFERENCE

Pacific Cod *(Gadus macrocephalus)* assessment for Queen Charlotte Sound (5AB), British Columbia in 2013

Regional Peer Review – Pacific Region

December 8, 2014 Nanaimo, British Columbia
Chairperson: Rowan Haigh

Context

Pacific Cod (*Gadus macrocephalus*) is a commercially important species of cod that occurs along the entire coast of British Columbia, Canada. The majority of catches are taken in Hecate Strait and Queen Charlotte Sound, where abundance is highest, although large catches have also been taken off the West Coast of Vancouver Island. Pacific Cod are taken by the groundfish trawl fishery and occasionally by hook and line fisheries.

A coastwide assessment of Pacific Cod has been requested by the Fisheries Management Branch of Fisheries and Oceans Canada (DFO). An updated Area 5AB assessment has not been received for the past 2 generations for this species. This meeting will review the area 5AB assessment of Pacific Cod including revisions as recommended at the January 9-10, 2014 Regional Peer Review. Given the apparent high productivity of Pacific Cod, updated advice has been requested to respond to changes in stock abundance in a timely manner.

Objectives

Guided by the DFO Sustainable Fisheries Framework, particularly the *Fishery Decision-making Framework Incorporating the Precautionary Approach* (DFO 2009), meeting participants will review the following working paper to provide the basis for discussion and advice on the specific objectives outlined below.

R.E. Forrest, K.L. Rutherford, L. Lacko, A.R. Kronlund, P.J. Starr. Assessment of Pacific Cod (Gadus macrocephalus) for Queen Charlotte Sound (5AB). CSAP working paper 2014-15/P22.

The working paper will be used to provide advice with respect to the following objectives:

- Recommend reference points consistent with the DFO Precautionary Approach. Include the biological considerations and rationale used to make such a determination.
- Evaluate the current status of Pacific Cod in Area 5AB relative to the recommended reference points.
- Evaluate the consequences of varying constant catches on future population status, providing decision tables and figures of projected biomass.
- Evaluate the performance of alternative model structures on decision-making.

Expected Publications

- CSAS Science Advisory Report
- CSAS Research Document

Participation

- DFO (Science, Fisheries Management, Oceans, Habitat)
- Aboriginal communities
- Province of British Columbia
- External reviewers

- Industry
- Non-governmental organizations and other scientists and stakeholders.

References

DFO. 2009. A fishery decision-making framework incorporating the Precautionary Approach.

APPENDIX B: WORKING PAPER REVIEWS

REVIEW – CAIHONG FU

Date: December 3, 2014

Reviewer: Caihong Fu, Conservation Biology, MEAD, PBS, DFO Canada

CSAS Working Paper: 2014-15/GF11

Working Paper Title: Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait (5CD) and Queen Charlotte Sound (5AB) in 2013 (revised)

I think the authors have adequately addressed the issues related to priors and recruitment anomalies in relation to sea levels, here I will only comment on Appendix D. Figures D8a and D8b are rather useful to see the actual length frequency data and see the changes from one time period (prior to 1996) to another (after 1996) in 5CD. I wonder why the same was not done for 5AB. Although the original query was considered flawed, it has some value to show both sets of raw length frequency data for 5AB for comparison purposes. So it will be nice to see Figure D1 be expanded to Figures D1a and D1b (just like Figures D8a and D8b).

From Figures D8a and D8b, we can see that there is no big differences between the length frequency data patterns of the "Keepers" prior to 1996 and those of "Unsorted" after 1996 for 5CD, and this is why even if the query is updated, the results won't change much. However, the differences between the length frequency data patterns of the "Keepers" prior to 1996 and those of all samples after 1996 in 5AB are enormous. The declining trend in mean length (Figure D5) for 5AB is evident; I suspect (do not expect the authors to respond) that the much reduced mean length may have contributed to the difficulty in converging and high auto-correlation in R_{Avg_init}. This noted differences in length frequency data between 5CD and 5AB may imply two possibilities.

1. There are some distributional differences between younger and older cod, i.e., younger cod tended to stay in 5AB. This distributional differences among different age groups are not uncommon, and hake is an example (older fish tend to move further north).
2. Spatial distributions may have changed over time or after 1996 with younger cod moving southward; looking into the spatial distribution changes of other similar species may help to get better understanding on this.

Regardless what may have happened, it is recommended that spatial distributions and stock structure in these two areas be studied in order to achieve more credible stock assessment; failure to consider these factors will bias the stock assessment.

The Five Questions

1. Is the purpose of the working paper clearly stated?

   YES

2. Are the data and methods adequate to support the conclusions?

   YES

3. Are the data and methods explained in sufficient detail to properly evaluate the conclusions?

   YES

4. If the document presents advice to decision-makers, are the recommendations provided in a useable form, and does the advice reflect the uncertainty in the data, analysis or process?

   YES

5. Can you suggest additional areas of research that are needed to improve our assessment abilities?

   Spatial distributions and stock structure in these two areas (5AB and 5CD) should be studied in order to achieve more credible stock assessment; failure to consider these factors will bias the stock assessment.

REVIEW – JAMES THORSON

Review for the Assessment of Pacific Cod (*Gadus macrocephalus*) for Hecate Strait (5CD) and Queen Charlotte Sound (5AB) in 2013

James Thorson, Dec 4, 2014

Summary

In these revisions to the previous assessment for Pacific cod in HS (5CD) and QCS (5AB), the authors have responded to concerns that were raised regarding the assembly and processing of data for QCS (5AB). The previous review identified concerns with the assembly of average weight data prior to the use of observers, as well as the order-of-operations when calculating average weight from length samples. Both concerns have been rectified, and the current assessment should be suitable as a basis for fisheries management advice. I applaud the authors for having the patience and diligence to respond to these concerns as thoroughly as they have.

In my previous review, I remember arguing for the use of previous results as suitable as the basis for management advice, and the authors disagreeing and suggesting this 2nd review meeting. I note that there is plenty of scientific evidence suggesting that delays between providing scientific advice and implementing changes in management measures is detrimental to long-term management performance. I therefore strongly recommend that this existing model be used for management advice for both 5AB and 5CD, unless there are serious concerns that arise during the in-person segment of the review.

Despite this, I have identified a few issues that I believe should be listed in the assessment document as priorities for future research. Issues such as these should not inhibit the use of the existing assessment for providing scientific advice, but also should be responded to during subsequent revisions of the assessment.

Major points

1. The authors note their concerns that length data prior to observers represent port-side samples of retained individuals, while after observers they represent both retained and potentially discarded individuals. Given that post-observer data includes information regarding which of the caught fishes are retained, it seems that post-observer data could be used to estimate both a selectivity curve, and a separate retention curve (where each could be logistic at age, at size, etc.), which is similar to how this issue is treated is stock synthesis. Assuming that these curves are constant over time, these could then be used to account for the difference in data prior to and after observers (i.e., by treating pre-observer data as representing retained individuals only, and hence arising from the

product of selectivity and retention curves). This is particularly important, given that the average-weight data are used to bridge between indices in early and late years.

2. The above point would obviously require moving to a fully age-structured model. As noted in my previous review, the current delay-difference model is identical to an age-structured model, given that growth in weight follows a von Bertalanffy curve, selectivity is knife-edged at age at maturity, etc. Given this duality, I think using an age-structured model would allow estimates of selectivity if using full composition data (rather than just average weight). Data weighting could then be designed to ensure similarity to the delay-difference model.

3. I also still think that the leading parameters used for data-weighting are difficult to interpret and should be reconsidered. In simple contexts at least, variances in a hierarchical model are additive, and this implies that the variance for a data stream like average weight can never be less than the sampling variance that is calculated from the number of tows sampled, sample sizes across quarters, etc. I remember concluding that the data-weighting method used does not ensure that variances are treated as additive, and hypothesize that a different treatment of data weighting could clarify the decisions regarding data weighting that are made in the current assessment. However, I don't think this is a huge issue, given results from the sensitivities that the authors provide.

APPENDIX C: AGENDA

Canadian Science Advisory Secretariat
Centre for Science Advice Pacific

Regional Peer Review (RPR) Meeting

Assessment of Pacific Cod (*Gadus macrocephalus*) for Queen Charlotte Sound (5AB) in 2013

Dec 8, 2014
Pacific Biological Station, Nanaimo BC

Chair: Rowan Haigh

Time	Subject	Presenter
0900	Introductions Review Agenda & Housekeeping CSAS Overview and Procedures	Chair
0915	Review Terms of Reference	Chair
0930	Presentation of Working Paper	Author(s)
1030	***Break (15 min)***	
1045	Written Reviews (Main Discussion Points)	Reviewers & Authors
12:00	***Lunch Break (1 hour)***	
1300	Group Discussion & Resolution of Technical Issues	Group
1400	Identification of Key Issues	RPR Participants
1430	***Break (15 min)***	
1445	Develop Consensus on Paper Acceptability (Instructions to Authors/RPR Recommendations)	RPR Participants
1515	Science Advisory Report (SAR) Develop consensus on the following: • Sources of Uncertainty • Results & Conclusions • Additional advice to Management (as warranted)	RPR Participants
1630	Adjourn for the Day	

APPENDIX D: PARTICIPANTS

Last Name	First Name	Affiliation
Acheson	Schon	DFO Science, Groundfish Section
Ackerman	Barry	DFO Fisheries Management, Groundfish
Edwards	Andrew	DFO Science, Groundfish Section
Forrest	Robyn	DFO Science, Groundfish Section
Fu	Caihong	Science, Conservation Biol. Section
Govender	Rhona	Canadian Parks and Wilderness Society
Grandin	Chris	DFO Science, Groundfish Section
Haigh	Rowan	DFO Science, Groundfish Section
Hargreaves	Marilyn	Science, CSAP
Harling	Wayne	Sport Fishing Advisory Board (SFAB)
King	Jackie	DFO Science, Groundfish Section
Krishka	Brian	DFO Science, Groundfish Section
Lecomte	Jean-Baptiste	NSERC Visiting Fellowship
MacDougall	Lesley	DFO Science, Centre for Science Advice Pacific
Rutherford	Kate	DFO Science, Groundfish Section
Starr	Paul	Canadian Groundfish Conservation Society & External Expert
Surry	Maria	DFO Science, Groundfish Section
Thorson	Jim	NWFSC/ NMFS/ NOAA
Mose	Brian	CIC Trawl
Turris	Bruce	BC Groundfish Conservation Society
Thompson	Jason	Council of the Haida Nation
Workman	Greg	DFO Science, Groundfish Section
Wyeth	Malcolm	DFO Science, Groundfish Section